

What is Claimed Is:

1. A method of manufacturing granular perpendicular magnetic recording media, comprising sequential steps of:
  - (a) providing a non-magnetic substrate including a surface;
  - (b) forming a layer stack on said surface of said substrate, said layer stack including a granular perpendicular magnetic recording layer having an exposed upper surface;
  - (c) generating a plasma containing at least one ionized oxygen species derived from a source gas comprised of a compound of oxygen and at least one other non-metallic element; and
  - 10 (d) treating said exposed upper surface of said granular perpendicular magnetic recording layer with said plasma to form an oxidized surface layer.
2. The method according to claim 1, wherein:  
step (a) comprises providing a non-magnetic substrate comprised of a non-magnetic material selected from the group consisting of Al, NiP-plated Al, Al-Mg alloys, other Al-based alloys, other non-magnetic metals, other non-magnetic  
5 alloys, glass, ceramics, polymers, glass-ceramics, and composites and/or laminates of the aforementioned materials.
3. The method according to claim 1, wherein:  
step (b) comprises forming a layer stack including a granular Co-based alloy perpendicular magnetic recording layer comprised of a CoPtX alloy, where X = at least one element or material selected from the group consisting of: Cr, Ta,  
5 B, Mo, V, Nb, W, Zr, Re, Ru, Cu, Ag, Hf, Ir, Y, O, Si, Ti, N, P, Ni, SiO<sub>2</sub>, SiO, Si<sub>3</sub>N<sub>4</sub>, Al<sub>2</sub>O<sub>3</sub>, AlN, TiO, TiO<sub>2</sub>, TiO<sub>x</sub>, TiN, TiC, Ta<sub>2</sub>O<sub>5</sub>, NiO, and CoO, and wherein Co-containing magnetic grains with *hcp* lattice structure are segregated by grain boundaries comprising at least one of oxides, nitrides, and carbides.

4. The method according to claim 1, wherein:

- step (b) comprises forming a layer stack including a granular Co-based alloy perpendicular magnetic recording layer comprised of a CoPtX alloy, where X = at least one element or material selected from the group consisting of: Cr, Ta,  
5 B, Mo, V, Nb, W, Zr, Re, Ru, Cu, Ag, Hf, Ir, Y, O, Si, Ti, N, P, Ni, SiO<sub>2</sub>, SiO, Si<sub>3</sub>N<sub>4</sub>, Al<sub>2</sub>O<sub>3</sub>, AlN, TiO, TiO<sub>2</sub>, TiO<sub>x</sub>, TiN, TiC, Ta<sub>2</sub>O<sub>5</sub>, NiO, and CoO, and wherein Co-containing magnetic grains with *hcp* lattice structure are segregated by grain boundaries comprising oxides.

5. The method according to claim 4, wherein:

- step (b) comprises forming said granular Co-based alloy perpendicular magnetic recording layer by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species  
5 derived from a source gas comprised of a compound of oxygen and at least one other non-metallic element.

6. The method according to claim 5, wherein:

- step (b) comprises forming said granular Co-based alloy perpendicular magnetic recording layer by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species  
5 derived from a source gas selected from the group consisting of: nitrogen oxides, sulfur oxides, and carbon oxides.

7. The method according to claim 6, wherein:

- step (b) comprises forming said granular Co-based alloy perpendicular magnetic recording layer by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species  
5 derived from a source gas selected from the group consisting of: NO, NO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>4</sub>, SO<sub>2</sub>, CO, and CO<sub>2</sub>.

8. The method according to claim 1, wherein:

step (c) comprises generating said plasma containing at least one ionized oxygen species from a source gas selected from the group consisting of: nitrogen oxides, sulfur oxides, and carbon oxides.

9. The method according to claim 8, wherein:

step (c) comprises generating said plasma containing at least one ionized oxygen species from a source gas selected from the group consisting of: NO, NO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>4</sub>, SO<sub>2</sub>, CO, and CO<sub>2</sub>.

10. The method according to claim 8, wherein:

step (c) comprises generating a DC, RF, or microwave plasma.

11. A method of manufacturing granular perpendicular magnetic recording media, comprising sequential steps of:

- (a) providing a non-magnetic substrate including a surface;
- (b) forming a layer stack on said surface of said substrate, said layer stack including a granular perpendicular magnetic recording layer having an exposed upper surface and formed by reactively sputtering a target comprised of a magnetic alloy in an atmosphere containing at least one ionized oxygen species derived from a source gas comprised of a compound of oxygen and at least one other non-metallic element; and
- 5 (c) treating said exposed upper surface of said granular perpendicular magnetic recording layer with an oxygen-containing gas to form an oxidized surface layer.

12. The method according to claim 11, wherein:

step (a) comprises providing a non-magnetic substrate comprised of a non-magnetic material selected from the group consisting: of Al, NiP-plated Al, Al-Mg alloys, other Al-based alloys, other non-magnetic metals, other non-magnetic

5 alloys, glass, ceramics, polymers, glass-ceramics, and composites and/or laminates of the aforementioned materials.

13. The method according to claim 11, wherein:

step (b) comprises forming a layer stack including a granular Co-based alloy perpendicular magnetic recording layer comprised of a CoPtX alloy, where X = at least one element or material selected from the group consisting of: Cr, Ta,  
5 B, Mo, V, Nb, W, Zr, Re, Ru, Cu, Ag, Hf, Ir, Y, O, Si, Ti, N, P, Ni, SiO<sub>2</sub>, SiO, Si<sub>3</sub>N<sub>4</sub>, Al<sub>2</sub>O<sub>3</sub>, AlN, TiO, TiO<sub>2</sub>, TiO<sub>x</sub>, TiN, TiC, Ta<sub>2</sub>O<sub>5</sub>, NiO, and CoO, and wherein Co-containing magnetic grains with *hcp* lattice structure are segregated by grain boundaries comprising oxides.

14. The method according to claim 13, wherein:

step (b) comprises forming said granular Co-based alloy perpendicular magnetic recording layer by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species  
5 derived from a source gas selected from the group consisting of: nitrogen oxides, sulfur oxides, and carbon oxides.

15. The method according to claim 14, wherein:

step (b) comprises forming said granular Co-based alloy perpendicular magnetic recording layer by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species  
5 derived from a source gas selected from the group consisting of: NO, NO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>4</sub>, SO<sub>2</sub>, CO, and CO<sub>2</sub>.

16. The method according to claim 11, wherein:

step (c) comprises generating a plasma containing at least one ionized oxygen species derived from a source gas comprised of a compound of oxygen and at least one other non-metallic element, and treating said exposed upper

5 surface of said granular perpendicular magnetic recording layer with said plasma to form said oxidized surface layer.

17. The method according to claim 16, wherein:

step (c) comprises generating said plasma containing at least one ionized oxygen species from a source gas selected from the group consisting of: nitrogen oxides, sulfur oxides, and carbon oxides.

18. The method according to claim 17, wherein:

step (c) comprises generating said plasma containing at least one ionized oxygen species from a source gas selected from the group consisting of: NO, NO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>4</sub>, SO<sub>2</sub>, CO, and CO<sub>2</sub>.

19. The method according to claim 16, wherein:

step (c) comprises generating a DC, RF, or microwave plasma.

20. A granular perpendicular magnetic recording medium, comprising:

(a) a non-magnetic substrate having a surface; and

(b) a layer stack on said surface of said substrate, said layer stack including a granular perpendicular magnetic recording layer formed by:

5 (1) reactively sputtering a target comprised of a magnetic alloy in an atmosphere containing at least one ionized oxygen species derived from a source gas comprised of a compound of oxygen and at least one other non-metallic element; and

10 (2) oxidizing an exposed upper surface of said granular perpendicular magnetic recording layer by generating a plasma containing at least one ionized oxygen species derived from a source gas comprised of a compound of oxygen and at least one other non-metallic element, and treating said exposed upper surface of said granular perpendicular magnetic recording layer with said plasma.

21. The medium as in claim 20, wherein:

said substrate is comprised of a non-magnetic material selected from the group consisting of: Al, NiP-plated Al, Al-Mg alloys, other Al-based alloys, other non-magnetic metals, other non-magnetic alloys, glass, ceramics, polymers, glass-ceramics, and composites and/or laminates of the aforementioned materials; and

5 said layer stack includes a granular Co-based alloy perpendicular magnetic recording layer comprised of a CoPtX alloy, where X = at least one element or material selected from the group consisting of: Cr, Ta, B, Mo, V, Nb, W, Zr, Re, Ru, Cu, Ag, Hf, Ir, Y, O, Si, Ti, N, P, Ni, SiO<sub>2</sub>, SiO, Si<sub>3</sub>N<sub>4</sub>, Al<sub>2</sub>O<sub>3</sub>, AlN, TiO,  
10 TiO<sub>2</sub>, TiO<sub>x</sub>, TiN, TiC, Ta<sub>2</sub>O<sub>5</sub>, NiO, and CoO, and wherein Co-containing magnetic grains with *hcp* lattice structure are segregated by grain boundaries comprising oxides.

22. The medium as in claim 21, wherein:

said granular Co-based alloy perpendicular magnetic recording layer is formed by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species derived from a source  
5 gas comprised of a compound of oxygen and at least one other non-metallic element; and said exposed upper surface of said magnetic recording layer is oxidized by treatment with a plasma containing at least one ionized oxygen species derived from a source gas comprised of a compound of oxygen and at least one other non-metallic element.

23. The medium as in claim 22, wherein:

said granular Co-based alloy perpendicular magnetic recording layer is formed by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species derived from a source  
5 gas selected from the group consisting of: nitrogen oxides, sulfur oxides, and carbon oxides; and said exposed upper surface of said magnetic recording layer is

oxidized by treatment with a plasma containing at least one ionized oxygen species derived from a source gas selected from the group consisting of: nitrogen oxides, sulfur oxides, and carbon oxides.

24. The medium as in claim 23, wherein:

said granular Co-based alloy perpendicular magnetic recording layer is formed by reactively sputtering a target comprised of said CoPtX alloy in an atmosphere containing at least one ionized oxygen species derived from a source 5 gas selected from the group consisting of: NO, NO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>4</sub>, SO<sub>2</sub>, CO, and CO<sub>2</sub>; and said exposed, upper surface of said magnetic recording layer is oxidized by treatment with a plasma containing at least one ionized oxygen species derived from a source gas selected from the group consisting of: NO, NO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>4</sub>, SO<sub>2</sub>, CO, and CO<sub>2</sub>.